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Engineering Study for Waste Package and Cask Trolleys Design Development Plan

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DISCLAIMER

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WASTE PACKAGE AND CASK TROLLEYS

DESIGN DEVELOPMENT PLAN

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CHANGE HISTORY

Revision Number	Interim Change No.	Approval Date	Description Of Change
00A		05/31/2005	Initial Issue
000		06/08/2005	Added section 12.4 and made a few editorial changes

CONTENTS

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TABLES

ACRONYMS

DDP	design development plan
FMEA	failure mode and effects analysis
FTA	fault tree analysis
ITS	important to safety
NSDB	Nuclear Safety Design Basis
SSCs	structures, systems, and components

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1. PURPOSE

The purpose of this design development plan (DDP) is to identify major milestones for advancing the design of the waste package and cask trolleys to meet their credited safety functions as identified in the *Nuclear Safety Design Bases for License Application* (NSDBLA), (BSC 2005 [DIRS 171512]), where this objective cannot be achieved by the use of commercially available components or the application of industry consensus codes and standards. Furthermore, this DDP will define the planned approach and schedule logic ties for the design development activities, if and when required, and provides the basis for the subsequent development of performance specifications, test specifications and test procedures. At this time no design development needs have been identified for the waste package and cask trolleys.

2. SCOPE

The scope and extent of this DDP is driven by development requirements defined within the *Engineering Study for Waste Package and Cask Trolleys Gap Analysis*, (BSC 2005 [DIRS 173906]). This DDP applies to areas of the waste package and cask trolleys design where performance acceptance cannot be readily obtained through the use of commercially available structures, systems, and components (SSCs), or use of consensus codes and standards, in conjunction with a recognized equipment qualification program. Since no such areas have been identified in the gap analysis, this document outlines the approach that will be used should design development requirement be identified as the design advances.

The scope of this DDP is limited to identifying the planned approach and design development activities necessary to advance the design of the waste package and cask trolleys to demonstrate that it meets its credited safety functions. Thereafter, this DDP will form the basis for defining design development and testing requirements within the waste package and cask trolleys performance specification. The performance specification will define the codes, standards, and performance requirements for design, fabrication, and testing of the equipment. Testing activities will be detailed in test specifications and test procedures. Test specifications will detail the requirements for each test, and testing procedures will prescribe how each test is to be performed.

This DDP was prepared by the Fuel Handling Facility project team and is intended for the sole use of the Engineering department in work regarding the waste package and cask trolleys. Yucca Mountain Project personnel from the Fuel Handling Facility project team should be consulted before using this DDP for purposes other than those stated herein or for use by individuals other than those authorized by the Engineering department.

3. PROGRESSIVE APPROACH

Design development requirements and activities identified in this DDP are commensurate with the level of design completed for the License Application and the associated gap analysis study. Therefore, specific design details and the selection of specific SSCs may not be known, and all design development requirements may not have been identified in the gap analysis study.

Therefore, a progressive design development approach is presented in this DDP that provides a framework for identifying and detailing design development requirements and activities as the design advances. It is anticipated that as the design matures, to the extent practicable, SSCs that perform ITS functions will be selected based on proven technology and codes and standards that provide assurance they will perform as required without need for extensive design development.

The progressive design development approach includes, as appropriate, the design development activities identified in Section 9.0. Completion of each design development activity and advancement of the design will determine the need for further design development and completion of additional design development activities.

In addition, the progressive approach maintains flexibility throughout the design process to allow alternative solutions to be explored without compromising design development objectives.

4. DESIGN DEVELOPMENT OBJECTIVES

It can be seen from the *Engineering Study for Waste Package and Cask Trolleys Gap Analysis*, (BSC 2005 [DIRS 173906]) that all of the nuclear safety design requirements for the waste package and cask trolleys have been satisfied through the application of codes and standards and no design development requirements were identified. Therefore, the design activities described in sections 9 and 10 are not currently needed but included for completeness for possible use at a later date as the design advances. Full testing of standard SSCs as identified in the *Engineering Study for Waste Package and Cask Trolleys Gap Analysis*, (BSC 2005 [DIRS 173906]) will be included in the performance specification at a later date.

5. QUALITY ASSURANCE

This document was prepared in accordance with LP-ENG-014-BSC, *Engineering Studies*. The results of this document are to be used only as the basis for selecting design development activities; they are not to be used directly to generate quality products. Therefore, this engineering study is not subject to requirements of the *Quality Assurance Requirements and Description* document (DOE 2004 [DIRS 171539]).

6. USE OF COMPUTER SOFTWARE

The computer software used in this study (Microsoft Word 2000) is classified as exempt from procedure LP-SI.11Q-BSC, *Software Management*. All software used to prepare this analysis is listed as "software not subject to this procedure" (LP-SI.11Q-BSC, Section 2.1).

7. FUNCTIONAL DESCRIPTION

The trolley is a specialized piece of equipment that lifts and transports casks/WPs through the main operational areas of the Fuel Handling Facility (FHF), Canister Handling Facility (CHF) and the Dry Transfer Facility (DTF). The trolley will be self-propelled, ride on a rail system and will be primarily automated, although hands-on operations will be permitted dependent upon payload. The waste package and cask trolleys will be fully adjustable to accommodate the varying diameters and lengths of the casks/WPs and will provide structural support during transport and seismic events. The waste package and cask trolleys will support the casks/WPs by the upper trunnions and transport them a few inches above the floor.

The waste package and cask trolleys are based on nuclear crane technology and are similar in concept to a gantry crane, straddle carrier or container loader crane. The elements of the design take proven design concepts and use them for this application. The waste package and cask trolleys utilization is relatively low for crane industry standards. However, the radiation levels and ambient temperatures create a harsh operating environment. Because of the harsh environment, all waste package and cask trolleys operations will be performed remotely, and special consideration will be given to the materials of construction and reliability of the components. In addition, special consideration will be given to remote recovery operations such as the ability for the equipment to maintain a safe condition and to return safely to normal operations during and after system or component failures and during and after a natural phenomenon such as seismic events.

8. NON-STANDARD STRUCTURES, SYSTEMS, AND COMPONENTS

Non-standard SSCs are defined as; SSCs not based on commercially available equipment, established industry practices, or consensus codes and standards. The preferred practice is to use standard components and SSCs where the failure modes, failure effects, and reliability values are documented under similar operating conditions and environments.

The *Engineering Study for Waste Package and Cask Trolleys Gap Analysis*, (BSC 2005 [DIRS 173906]) identified SSCs that perform ITS functions, and it identified the codes and standards to be used to provide assurance that the ITS SSCs will perform as required. In all cases, ITS functions and requirements could be met using standard SSCs and using codes and standards developed for nuclear applications. The *Engineering Study for Waste Package and Cask Trolleys Gap Analysis*, (BSC 2005 [DIRS 173906]) did not identify any non-standard SSCs that require design development.

9. DESIGN DEVELOPMENT ACTIVITIES

The following design development activities represent the progressive design development approach to advance the waste package and cask trolleys design should the need for design development be identified in the future. In turn, as the design advances, the need to complete each design development activity (or selectively complete activities) should be determined based on meeting each credited safety function. Design development activities are described in Section 10.

As previously noted and reflected in Appendix A, this section does not currently apply to the waste package and cask trolleys since no design development needs have been identified. It is included to describe the methodology that may be applied if design development needs are *identified in the future.*

- Design Activities:
  - Selection of SSCs
  - Engineering calculations
  - Computer modeling
  - Failure modes and effect analysis
  - Fault tree analysis (FTA)
- Testing Activities:
  - Bench testing
  - Prototype testing
  - Integrated testing.

10. DESIGN DEVELOPMENT DESCRIPTIONS

As previously noted this section does not currently apply to the waste package and cask trolleys since no design development needs have been identified. It is included to describe the methodology that may be applied if design development needs are identified in the future.

10.1 SELECTION OF STRUCTURES, SYSTEMS, AND COMPONENTS

To the extent practicable, SSCs will be selected based on proven technologies that have been used in similar environmental and nuclear operating conditions. Selection of SSCs with proven nuclear pedigrees and well-documented histories may reduce the need for subsequent design development, and SSCs certified to IEEE Std 323™-2003, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations,* [DIRS 166907] may require little or no physical design development activities. In contrast, the selection of new technologies may require testing to confirm the adequacy of the equipment design under normal, abnormal, design basis event, and post-design basis event conditions, as well as the suitability of the materials and methods of construction.

10.2 ENGINEERING CALCULATIONS

As the design progresses and solutions are evaluated, especially for structural components, engineering calculations may be required to confirm that acceptable stress and strain levels are maintained and that maximum deflections are not exceeded. Validation of the SSCs may be demonstrated through calculations, and where necessary as a prerequisite to three-dimensional modeling and finite element modeling.

10.3 COMPUTER MODELING

Computerized, three-dimensional simulation modeling may be conducted for design verification during the advancement of the SSCs detail design to ensure that the SSCs will perform as required. Three-dimensional modeling may also be applied to the SSCs to verify performance acceptance as alternative design options are considered. Finite element modeling may be used during design development to provide evidence that design stress levels are not exceeded.

10.4 FAILURE MODE AND EFFECTS ANALYSIS

A failure mode and effects analysis (FMEA) may be performed on the SSCs using ANSI/IEEE Std 352-1987, *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems* [DIRS 124964]. Although FMEA has already been identified in the *Engineering Study for Waste Package and Cask Trolleys Gap Analysis*, (BSC 2005 [DIRS 173906]) as a standard activity to evaluate trolley response to loss of electrical power or spurious signals caused by fire, a description of the general methodology is included here for completeness.

The FMEA is usually the first reliability activity performed to provide a better understanding of the failure potential of a design. The FMEA may be limited to a qualitative assessment, but may include numerical failure probability estimates. Important applications of the FMEA include:

- Specifying future tests required to establish whether design margins are adequate relative to specific failure mechanisms identified in the FMEA
- Identifying “safe” and “unsafe” failures for use in the quantitative evaluation of safety-related reliability
- Identifying critical failures that may dictate the frequency of operational tests and maintenance intervals if the failure modes cannot be eliminated from the design
- Establishing the quality-level for parts (especially electrical parts) needed to meet reliability goals
- Identifying unacceptable failure mechanisms (failures that may produce unacceptable safety or operational conditions) and the need for design modifications to eliminate them
- Identifying the need for failure detection.

FMEA may be used to identify, by component, all known failure modes, failure mechanisms, effects on the system, the method of failure detection, and provisions in the design to compensate for the failures. The analysis may provide established reliability statistics based on failure rates for components used in similar applications and environmental conditions. Reliability data, where available, will be obtained from nuclear facilities with similar quality control requirements. This activity is a prerequisite to performing a detailed fault tree analysis, and it provides the first level of design validation during the conceptual design phase. The FMEA may be periodically updated to reflect changes in design as the design matures.

10.5 FAULT TREE ANALYSIS

The following Fault tree Analysis (FTA) standard may be used to perform a FTA on the SSCs using guidance in accordance with ANSI/IEEE Std 352-1987 (*IEEE Guide for General*

Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems) [DIRS 124964].

Where quantitative reliability requirements have been established in the *Nuclear Safety Design Bases for License Application* (BSC 2005 [DIRS 171512]) a fault tree analysis may be used to assess reliability. The fault tree analysis, performed in conjunction with the results of the FMEA, may provide adequate design validation to proceed with prototype testing. Important benefits of FTA include:

- Identifying possible system reliability and safety problems during the design phase
- Assessing system reliability and safety during operation
- Improving the understanding of the component interactions within a system
- Identifying components that may need testing or more rigorous quality assurance scrutiny
- Identifying root causes of equipment failures.

10.6 BENCH TESTING OF COMPONENTS

Components that do not have a proven history of operating in environments similar to those expected at Yucca Mountain may be subject to bench testing at a testing facility capable of handling and duplicating the SSCs bounding environmental conditions.

Bench testing may be used to validate the following, in consideration of the above mentioned conditions:

- Suitability of materials used in the construction of components and assemblies
- Methods and techniques used in the construction of assemblies
- Lubricants used in or on components and assemblies
- The surface-finish of the components and assemblies (natural or painted)
- Evidence that components and assemblies will function properly over their expected operating life.

10.7 PROTOTYPE TESTING

The basic approach for prototype testing is to test the SSCs in an environment that simulates the actual operating environment as closely as possible. Prototype testing may be performed at full-scale because some components are unavailable at reduced scale. Full-scale prototype testing is recommended because:

- Scalability of the results from a scale model is questionable for enclosure thermal life predictions.
- A scale model approach implies a throwaway model at the conclusion of testing. It is anticipated that the initial SSCs can be used as a production or training unit with minor modifications and refurbishment.
- It is questionable whether scale components are available in all cases.
- The full-scale prototype approach is likely the low-cost plan.

Full-scale testing may also provide the most representative information to the final production equipment. Selection of individual components may consider their influence on test results. Where practicable, components that are identified as ITS may be identical to those to be used in the final production unit.

Prototype testing may be performed in the following three phases:

- Phase I: Accelerated testing
- Phase II: Extended testing
- Phase III: Sustained testing.

Prototype testing may establish data for the predictable life of components. Data may be established for the mechanical drive trains, control components, and field-mounted devices that are susceptible to premature failure in harsh environments. These data are important for validating equipment performance and recovery operations and for demonstrating equipment maintenance. Testing may simulate accelerated component life cycles and operating environments.

10.7.1 Accelerated Testing

Accelerated testing may simulate the full life-cycle operations of SSCs for all moving parts (e.g., motors, gearboxes, shafts, brakes, and lead screws) in a compressed time period. This activity may also include full life-cycle control sequence testing of the control system, including the programmable logic controller, all control instrumentation, switches, sensors, and cabling. The control and instrumentation cabinets may be full life cycle tested relative to the SSCs environmental conditions.

ITS SSCs and typical prototype accelerated tests are listed in Table B-1, Appendix B. Currently there are no data collection requirements for the waste package and cask trolleys since no design development activities have been identified. Therefore Table B-1 is provided for information only.

10.7.2 Extended Testing

Extended testing may simulate extended life-cycle operations for all moving parts (e.g., motors, gearboxes, shafts, brakes, and lead screws) of the SSCs. This activity may also include full life-cycle control sequence testing of the control system, including the programmable logic controller, all control instrumentation, switches, sensors, and cabling. The control and instrumentation cabinets may also be full life cycle tested to the SSCs environmental conditions.

ITS SSCs and typical prototype accelerated tests are listed in Table B-1, Appendix B. Currently there are no data collection requirements for the waste package and cask trolleys since no design development activities have been identified. Therefore Table B-1 is provided for information only.

10.7.3 Sustained Testing

Sustained testing may simulate the SSCs performance under off-normal environmental and operational conditions. Off-normal conditions include, for example, high and low temperatures, over travel, collisions, off-set loads, loss of power, seizure of moving parts, derailments, and track misalignment. Details that may be considered during sustained testing, and the components to test include:

- All load path and linear travel components, testing at a minimum, moving parts seizure.
- All components of the lifting and linear travel control systems, testing may concentrate on, but not be limited to, loss of power, and spurious signals.
- The SSCs as whole may be subjected to track misalignment and a derailment simulation.

ITS SSCs and typical prototype accelerated tests are listed in Table B-1, Appendix B. Currently there are no data collection requirements for the waste package and cask trolleys since no design development activities have been identified. Therefore Table B-1 is provided for information only.

10.8 OFF-SITE INTEGRATED TESTING

Off-site integrated testing may be performed to demonstrate relevant interfaces. Furthermore an off-site test facility may also serve as an operator training facility. Integrated testing may be fully representative, to the extent practicable, of real operations with the exception of a radioactive environment.

Due to the nature of the SSCs, integrated testing is recommended to support the following goals:

- Demonstrate functionality of the complete system under simulated operational conditions
- Demonstrate the practicality of recovery and retrieval plans
- Verify the system performance prior to delivery to site

- Provide preparation for operational readiness review
- Permit early hands-on involvement of regulatory agencies
- Permit early operator training capabilities
- Provide early feedback for necessary modifications or design enhancements.

10.9 OPERATIONAL READINESS REVIEW

Although the operational readiness review is beyond the scope of this DDP, it is mentioned here for completeness. An operational readiness review may follow off-site integrated testing and highlights the final milestone in demonstrating the performance of production ITS SSCs.

11. INFORMATION COLLECTION AND INSPECTION REQUIREMENTS

Although, individual components may be selected based on previous use in similar nuclear applications, it is unlikely that they have been used within the same configuration or for exactly the same application, and therefore component failure or excessive wear may be influenced by unknown interactions. Therefore, to evaluate component failures, it is essential that information be collected during each stage of the component life (i.e., manufacture, construction and operation). This information may then be used to ensure that a root cause analysis can be performed on the components that do not meet design and performance objectives.

Typical data collection requirements for ITS SSCs are listed in Table C-1, Appendix C. Currently there are no data collection requirements for the waste package and cask trolleys since no design development activities have been identified. Therefore Table C-1 is provided for information only.

11.1 BASELINE DATA

To assess wear and failure modes of ITS components, it is essential that detailed baseline data be obtained. The data, at a minimum, may include a physical inspection of each component before and after installation to identify defects and anomalies. All noted defects and anomalies must be addressed prior to testing. Typical data may include weights, important dimensions, and surface finishes.

11.2 ACCELERATED TEST DATA

Throughout life-cycle prototype testing, sufficient instrumentation may be provided to monitor the performance of ITS components. Instrumentation may provide real-time monitoring and feedback on important measurements and operating parameters. Measurements, at a minimum, may include.

- The effects of temperature on components and fabrications caused by environmental temperatures coupled with the heat developed by components during operation (e.g., lead screws, motors, gearboxes, bearings, speed control equipment, sensors, switches, cables, and relays).

- The ventilation system for the control cabinets may be monitored to ensure acceptable temperatures for the electronic components (e.g., switches, relays, and cables).

- The effects of the design loads on all load bearing components and fabrications may be monitored for stress and strain levels, physical deflections, and reductions in surface finish on load-path components (e.g., shafts, bearings, and lead screws) caused by wear.

- Motor power requirements may be recorded during the operations of linear movement, lifting, and lowering.

- The linear drive and load path components (e.g., motors, gearboxes, bearings, and lead-screws) may be monitored for vibration and sound during operating cycles.

- The speed control systems for linear travel and lifting may be monitored under all conditions.

Instrumentation where practicable may include visual and audible feedback.

During accelerated testing, components may be inspected and maintained (e.g., adjustments and lubrication) as part of a scheduled maintenance regime based on vendor data. Where practicable, supplement vendor data with predictive maintenance and condition-monitoring techniques.

11.3 EXTENDED TEST DATA

Data requirements for extended testing are similar to those for accelerated testing, with the exception that a detailed inspection of each ITS component needs to be performed prior to testing to determine component wear and life expectancy.

11.4 SUSTAINED TEST DATA

Data requirements for sustained testing are similar to those for accelerated testing, with the exception that a detailed inspection of each ITS component needs to be performed after each sustained test evolution to monitor for evidence of progressive fatigue, cumulative fatigue, and component failure.

11.5 OFF-SITE INTEGRATED TEST DATA

After prototype testing of individual components is complete, it may be necessary to demonstrate the overall functionality of the complete system. This phase of testing is referred to as integrated testing. To the extent practicable, integrated testing may be used to demonstrate the performance of the complete system under simulated operating conditions. Prior to off-site integrated testing, used equipment may be refurbished or replaced to new condition. Data collection for integrated testing may be fully representative of anticipated operating conditions.

12. EXPECTED RESULTS AND SUCCESS CRITERIA

The expected results and success criteria, based on satisfying the ITS performance requirements specified in *Nuclear Safety Design Bases for License Application* (BSC 2005 [DIRS 171512]), are outlined in this section. Deviations from expectations may be subjected to close inspection or further evaluation. If necessary, additional testing may be required to verify the data or to provide additional information for root cause analyses.

12.1 ACCELERATED TESTING

At the completion of accelerated testing, all ITS requirements specified in *Nuclear Safety Design Bases for License Application* (BSC 2005 [DIRS 171512]) should have been met.

To achieve these requirements, it is expected that the SSCs may not require any unplanned maintenance. Failure of ITS components within this period, results that are not consistent with vendor data, and bench testing may be closely evaluated to determine root causes for any failures or problems found.

12.2 EXTENDED TESTING

Extended testing may provide added confidence that ITS requirements can be met with a degree or margin over an extended operational life. Therefore, successful extended testing may conclude with results that further support accelerated testing. Extended testing may provide a basis for the timing of planned maintenance outages during which components and assemblies may be inspected and maintained.

12.3 SUSTAINED TESTING

Sustained testing may provide added confidence that ITS requirements can be met with a degree or margin under off-normal conditions. Therefore, successful sustained testing may conclude with results that further support accelerated and extended testing. Sustained testing may highlight potentially weak areas, demonstrate areas of unacceptable wear, and identify signs of fatigue. This testing may add confidence to the frequency of planned maintenance outages.

12.4 OFFSITE INTEGRATED TESTING

Off-site integrated testing will provide assurance the system will perform all required safety functions and that interactions with other equipment interfaces including recovery systems are as specified. During this testing, improvements may be highlighted that will be incorporated prior to delivery and installation of the equipment on site.

13. LOGIC TIES TO DESIGN ENGINEERING, PROCUREMENT, AND CONSTRUCTION

As stated previously, no design development requirements have been identified for the waste package and cask trolleys. The logic ties to Design Engineering, Procurement, and Construction organizations listed in Table D-1, Appendix D are listed as example only.

14. REFERENCES

14.1 DOCUMENTS CITED

171512 BSC (Bechtel SAIC Company) 2005. *Nuclear Safety Design Bases for License Application.* 000-30R-MGR0-00400-000-001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050308.0004.

171539 DOE (U.S. Department of Energy) 2004. *Quality Assurance Requirements and Description.* DOE/RW-0333P, Rev. 16. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20040907.0002

173906 BSC (Bechtel SAIC Company) 2005. *Engineering Study for Waste Package and Cask Trolleys Gap Analysis.* 210-30R-FH00-00200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company.

14.2 CODES, STANDARDS, AND PROCEDURES

124964 ANSI/IEEE Std 352-1987. *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems.* New York, New York: The Institute of Electrical and Electronics Engineers. TIC: 246332.

166907 IEEE Std 323™-2003. 2004. *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.* New York, New York: Institute of Electrical and Electronics Engineers. TIC: 255697.

LP-ENG-014-BSC, *Engineering Studies*

LP SI.11Q-BSC, *Software Management*

APPENDIX A ITS SSCS DESIGN DEVELOPMENT NEEDS

Table A-1. Design Development needs for the Waste Package and Cask Trolleys

NSDB Requirement	Applicable SSC	Design Development Needs					Comments
		Required Analysis	Required Drawings	Required Calculations	Required Modeling	Required Testing	
Upon a loss of power, this trolley shall be designed to stop, retain its load, and enter a locked mode; upon a restoration of power, this trolley shall stay in the locked mode until operator action is taken.	Locking device and control system SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
WP trolleys shall be designed for loading conditions associated with a DBGM-2 (design basis ground motion) seismic event and to demonstrate sufficient seismic design margin to ensure that a "no tipover" safety function is maintained for loading conditions associated with a BDBGM (beyond design basis ground motion) seismic event.	Structural, locking device, control system and rail SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
The trolley system shall be designed for loading conditions associated with a DBGM-2 seismic event to maintain trolley stability and prevent waste container slapdown. In addition, an analysis shall demonstrate that the trolley system has sufficient seismic design margin to ensure that a "no slapdown" safety function is maintained for loading conditions associated with a BDBGM seismic event.	Structural, locking device and control system SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
Pedestals and hold-down devices shall be designed for loading conditions associated with a DBGM-2 seismic event and to demonstrate sufficient seismic design margin to ensure a "no slapdown" safety function is maintained for loading conditions associated with a BDBGM seismic event.	Structural, locking device and control system SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements

NSDB Requirement	Applicable SSC	Design Development Needs					Comments
		Required Analysis	Required Drawings	Required Calculations	Required Modeling	Required Testing	
Pedestals and hold-down devices shall be designed for loading conditions associated with a DBGM-2 seismic event and to demonstrate sufficient seismic design margin to ensure that a "no tipover" safety function is maintained for loading conditions associated with a BDBGM seismic event.	Structural, locking device, control system and rail SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
The trolley shall be designed with an inherent speed limit such that a collision at the trolley speed limit would not cause the trolley to drop its load.	Structural, locking device and control system SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
Loaded transfer trolleys shall not derail or drop their loads.	Structural, locking device and rail SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
In the event of a credible fire in an area where waste forms are present, the temperature of the machinery that handles or transports SNF/HLW (spent nuclear fuel/high level waste) shall not reach a level that would make it drop its load.	Structural and locking device SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
A tipover and breach of a cask while on machinery that transports SNF/HLW due to uncontrolled movements produced by a loss of power or a spurious signal caused by a fire shall have a probability of less than 1×10^{-4} over the life of the facility.	Locking device and control system SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements

NSDB Requirement	Applicable SSC	Design Development Needs					Comments
		Required Analysis	Required Drawings	Required Calculations	Required Modeling	Required Testing	
The rails and rail anchorages within the structure shall be designed for loading conditions associated with a DBGM-2 seismic event. In addition, it shall be demonstrated that the rails and rail anchorages have sufficient seismic design margin to ensure that a "no derailment" safety function is maintained for loading conditions associated with a BDBGM seismic event.	Rail SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements

APPENDIX B PROTOTYPE TESTING FOR STRUCTURES, SYSTEMS, AND COMPONENTS IMPORTANT TO SAFETY

Table B-1. Typical prototype testing for structures, systems, and components important to safety

Structures, Systems, and Components Important to Safety	Test
• Structural frame	Accelerated and Extended Testing: • Life cycle load testing Sustained Testing: • Derailment simulation
Load Path Components: • Motors • Shafts • Gearboxes • Lead Screw • Brakes	Accelerated and Extended Testing: • Life cycle lift and lower testing Sustained Testing: • Seized components
Control systems: • Programmable logic controller • Instruments • Control & instrument cabinets • Switches and sensors • Cables • Electrical cabinets	Accelerated and Extended Testing: • Life cycle control sequence testing Sustained Testing: • Spurious signals
Long Travel Speed Components: • Wheel modules • Motors • Gearboxes • Position switches • Speed sensors	Accelerated and Extended Testing: • Life cycle long travel testing Sustained Testing: • Seized components

APPENDIX C DATA COLLECTION FOR STRUCTURES, SYSTEMS, AND COMPONENTS IMPORTANT TO SAFETY

Table C-1. Typical data collection for structures, systems, and components important to safety

Structures, Systems, and Components Important to Safety	Data Collection
• Structural frame	• Load measurements • Beam deflections • Stress and strain measurements • Non-destructive testing of welds
Load Path Components: • Motors • Shafts • Gearboxes • Lead Screw • Brakes	• Speed (shafts, motors) • Current, voltage (motors) • Temperature (lubricants, bearings, lead screws and nuts, motors) • Radiation (seals, lubricants) • Wear (bearings, shafts, brakes, lifting fingers, lead screws and nuts) • Surface finish (shafts) • Sound (gearbox, motors, bearings) • Contamination trap characteristics
Control systems: • Programmable logic controller • Instruments • Control & instrument cabinets • Switches and sensors • Cables	• Temperature (cabinets) • Current, voltage • Radiation (cable insulation, electronics, switches)
Long Travel Speed Components: • Wheel modules • Motors • Gearboxes • Position switches • Speed sensors • Electrical cabinets	• Wear (wheel flanges, bearings, gearboxes) • Current, voltage (motors) • Temperature (lubricants, bearings, lead screws and nuts, motors) • Radiation (seals, lubricants, switches, sensors) • Surface finish (shafts) • Sound (gearbox, motors, bearings)

APPENDIX D DESIGN DEVELOPMENT MILESTONES FOR THE WASTE PACKAGE AND CASK TROLLEYS

Table D-1. Example of design development milestones for the waste package and cask trolleys

Design Development Milestone	Description	Project Phase	P3 Logic Tie Activity ID	P3 Logic Tie Activity Description	Target Start	Target Finish
Contract award	Supplier review current design and provide feedback prior to final bid	Procurement – Design Engineering Subcontract	6 months	MH bid/Evaluate and award	TBD	TBD
Subcontract kickoff	Selected supplier discusses current design and their proposal and develops their design development schedule	Subcontract	2 months	Preliminary design	TBD	TBD
Failure mode and effect analysis	Detailed FMEA of design	Procurement - Design Engineering Subcontract	6 months	Preliminary design	TBD	TBD
Fault tree analysis	Detailed FTA of design	Procurement - Design Engineering Subcontract	6 months	Baseline design	TBD	TBD
Test specifications and test procedures	Test specifications and test procedures for bench testing and prototype testing	Procurement - Design Engineering Subcontract	3 months	Baseline design	TBD	TBD
Bench testing	Bench testing of ITS components	Procurement - Design Engineering Subcontract	2 months	Procurement and fabrication of components	TBD	TBD
Prototype testing – Phase I, II & III	Accelerated testing Extended testing Sustained testing	Procurement - Design Engineering Subcontract	5 months	Subcontract with testing facility test duration including shipping	TBD	TBD
Design process including vendor print review, fabrication etc	Detailed design and build including customer review	Procurement – Design Build Subcontract	9 months	Design and build	TBD	TBD

Integrated testing	Off-site integrated testing	Procurement – Design Build Subcontract	4 months	Offsite Integrated Testing	TBD	TBD

Within this table activity duration estimates have been included however the activities may be performed in series or where possible in parallel.